LEAF RUST ON WHEAT IN AUSTRALIA: A SYSTEMATIC SCHEME FOR THE CLASSIFICATION OF STRAINS.

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Synopsis.

The complications arising from the variability of the wheat leaf rust organism are reviewed and an attempt is made to systematize the nomenclature of strains. Use is made of reactions of the wheat varieties which are universally accepted as leaf rust differentials, but the supplemental varieties Thew, Gaza, Spica, Kenya W1483 and Klein Titan are added for further differentiation. The scheme is based on one now accepted by potato workers for use with the organism causing potato blight.

Leaf rust of wheat (*Puccinia recondita* Rob. ex Desm.) has been a disease of wheat known since the first work on the Australian cereal rusts was done (McAlpine, 1906). No extensive tests have been made to determine the importance of this organism in reducing yield in Australia, although a loss in yield of 14·5 per cent. has been suggested from the work of Phipps (1938). In North America the nature of the damage done by this organism is well known and it is generally considered that yield reductions result from fewer grains per head rather than reduced grain weight (Chester, 1946). Chester also figures a graph showing that extensive losses can occur if infection of a crop proceeds at an early stage and is followed by a defoliation of the plant. In Australia, frequently under nursery conditions and occasionally in commercial crops in northern New South Wales, the varieties Spica and Gabo are defoliated by leaf rust. Using the graph presented by Chester, one of us (I.A.W.) has estimated that approximately 10 per cent. of the yield may be lost due to this disease when the infection is severe.

The recent interest in and the cultivation of winter wheats have underlined further the importance of leaf rust. All varieties of winter wheat are at present susceptible and heavy infection follows an early autumn seeding. Defoliation of the plants at the tillering stage greatly reduces their attractiveness for grazing and builds up inoculum for dispersal to other crops during winter and spring.

The damage done by this disease has been recognized by several wheat breeders and efforts have been made to control it by developing resistant varieties. The fate of these latter and the strains that have been responsible for their susceptibility have recently been given by Watson *et al.* (1960).

During the course of the breeding programmes, extensive field surveys have been made to assess the variability of the organism. These surveys were conducted by Waterhouse from 1920 to 1952 and have been summarized (Waterhouse, 1952). He found in the very early stages of this work that the wheat varieties used in variability studies in North America gave an incomplete differentiation of the leaf rust strains present in this area. Thew and Gaza (a parent of Gabo) were added as supplemental varieties to the standard group. In order to catalogue the different rusts he used the letters A and B to designate resistance and susceptibility, respectively. A designation 135AB indicated the race number on the standard set of varieties and a resistant reaction on Thew but susceptibility on Gaza. Race 135BB was virulent on both Thew and Gaza. Many races were found by Waterhouse, but not all were incorporated into this system of nomenclature.

As the breeding programme expanded and the pathogenicity pattern of isolates of the leaf rust population became more complex, there has arisen a need for further modifications to the system of designating strains. With the widespread cultivation of

Spica (a variety believed to have the Hope type of resistance to leaf rust and stem rust), strains arose which were virulent on this variety as well as on Hope, H-44, Renown and other varieties related to them. The necessity for Spica or Renown as a supplemental variety additional to Thew and Gaza became evident and the separation of strains using all three varieties has already been given (Watson, 1958).

In a search for additional genes for resistance to leaf rust which may add genetic diversity to the parents used in breeding, extensive collections of species of *Triticum* have been tested with all known strains of leaf rust in this geographical area. Varieties resistant to all are regularly grown at several centres in New South Wales. Kenya W1483 was among several parents selected for its comprehensive resistance, but the breeding programme in which it figured had barely got under way when leaf rust was found in north Queensland to which this new parent is susceptible. Since 1959, when the first of the strains virulent on Kenya 1483 was found, there have been isolations in northern New South Wales, and it has become necessary to augment the supplementals still further by adding this variety. During the 1960–61 survey period a strain with some virulence on Klein Titan W2553 has been found, and this latter must also be added as a useful supplemental variety.

Procedure in Strain Identification.

As collections come from the field and at least 500 comprising leaf rust are dealt with in a normal season, they are first cultured on W1656 (C.I. 12632), a variety resistant to powdery mildew but with seedling susceptibility to all known local strains. From the resulting inoculum two isolated pustules are each separately increased on the same variety. Each collection is thus divided into two cultures which are expected to be relatively pure but could be dissimilar. The inoculum that develops from each single pustule isolate is used to infect seedlings of the following varieties: Webster, Mentana (representing Mediterranean) and Malakof from the standard group and Thew, Gaza, Spica and Kenya 1483 from the supplemental set. These seven varieties have in the past been adequate to describe the strain making up the original collection, but, as mentioned above, it has now become necessary to add Klein Titan.

From the results of these inoculations it is possible to classify the strain or strains present in the material. Where several strains were present in the collection some will be overlooked by this procedure. Two strains are frequently isolated from the one collection and the technique is considered more convenient than separating the original components by other means.

The spores remaining from the original inoculation of W1656 after the two single pustules have been taken are used to infect seedlings of varieties known to have a resistance effective against all local strains. Included with this group are varieties which, by virtue of a particular combination of genes for resistance, are specific for detecting strains which have the corresponding genes for pathogenicity. The known sources of resistance at present being used are Transfer W2382, La Prevision W1636, Rio Negro W2556, Colotana (266/51) W2555, Exchange W2554 and Timvera W1308. When seed is available this group will be increased by the addition of Aniversario W2097, Agrus W2502, Cornell Selection C.I. 13278, W2503, Dular W2500 C.I. 13373 and possibly some varieties of *T. durum*. At present it is not known whether certain genes for resistance are duplicated among this group, but until that information is available each will be treated as different.

La Prevision is highly resistant to all strains with which it has been tested and, while there is some variation in different environments in the reaction of Timvera seedlings, adult plants have remained very resistant. South Africa 43, originating from the same source, is also resistant to all strains.

The reactions of certain other varieties under trial as supplementals in North America to the Australian strains recently collected in the field are presented in Table 3. It will be apparent that these are not satisfactory as supplementary differentials for the leaf rust strains of Australia since several are resistant to all. These varieties represent a wide range of factors for resistance as shown by the following pedigrees, some of which were kindly supplied by Dr. R. M. Caldwell.

Agrus W2502 C.I. 13228 (Trumbull-*Agropyron elongatum*) × (Trumbull^3-Hope-Hussar × Fultz Selection 11845).

Newsar W2497 C.I. 12530 Trumbull × 3616 Al–1–1 = W38 × Fultz 11512 × Hungarian 4830–1.

Waban W2495 C.I. 12990 Wabash × American Banner.

Cornell 82 al–2–4–7C W2503 C.I. 13278 (Honor^2-Rosen Rye) × (Yorkwin × Cornell 595).

Wardal W2496 Wabash-American Banner × Warden-Leap.

Exchange W2554 C.I. 12635 Warden × Hybrid English.

Rio Negro W2556 C.I. 12469 Centenario × Supresa.

Lee W2084 C.I. 12488 Hope × Timstein.

Aniversario W2097 C.I. 12578 Reliance × Klein 75.

Transfer W2382 C.I. 13296 Chinese × *Aegilops umbellulata*.

Sinvalocho W2013 D.I.V. 4790 Sin Rival × 38 M.A. No. 32. Rafaela.

Klein Lucero W2012 D.I.V. 4094 Klein Progreso × Apulia.

W2518, a genetic stock which combines the genes from Mentana and from Malakof, is only susceptible to strain 122-Anz-1,2 which is virulent on both Mediterranean and Malakof. It serves to distinguish between collections of this strain from those which are mixtures of strains in which some components attack Malakof, others attack Mediterranean, but none is virulent on both. Other combinations of genes are being developed as testers to serve in the same way as W2518 but for other virulence genes, and it is expected they will increase the efficiency of the survey procedure.

The Difficulties of a Standardized Procedure.

Such complexity in the pathogenicity pattern has necessitated a simplification and standardization of nomenclature for the strains of the Australia-New Zealand area. It is desirable that plant breeders recognize the host range by the designation given to the strain and thus ensure that the appropriate strains are responsible for the epiphytotics developed in their nurseries.

North American workers have been confronted with similar problems of differentiation and designation of strains and at present are studying the most suitable varieties that will serve in that geographical area (Loegering *et al.*, 1960). Extensive acreages of wheat, the aerial movement of spores through several countries and the difficulties of co-ordination have not helped to simplify the problem for them.

It has become apparent over the years that the standard group of differential varieties given by Johnston and Levine (1955) is still useful where leaf rust is important. It is equally clear that these varieties are inadequate for an ultimate description sufficiently accurate to be of use to plant breeders in any area. Attempts to reach agreement on a group of varieties that would meet the requirements throughout the world are scarcely worth while, as the predominant genes and combinations of genes for pathogenicity differ very much from one geographical area to another. For each area the most effective group of genes for separating strains at any one time can be readily selected. Such a group must be augmented from time to time as man's efforts in breeding change the frequency of pathogenicity genes in the leaf rust population. Possibly, as breeders resort to the same sources of resistance throughout the world, a common group of host differential genes may become universally acceptable. For example, Renown and Lee may serve as differentials in North America; their counterparts of related origin in Australia and New Zealand are Spica and Gaza. Such a convergence is being hastened by the ready exchange of material now taking place through the medium of the International Rust Nurseries. These interchanges of material may bring uniformity in the differentials sooner than we expect.

Differentiation of Strains in the Australia-New Zealand Area.

The multiplicity of strains of leaf rust that have developed as the breeding programmes advanced would never have been predicted when the early studies were initiated by Waterhouse. From 1920 to 1945, when no leaf rust resistant varieties of any consequence were grown commercially, only two important races of leaf rust occurred in the field, although others were known. With the cultivation of Gabo, Waterhouse records the finding of four additional races (Waterhouse, 1952). There have been some shifts in the varieties cultivated in Australia since then. Festival and Spica have increased in popularity, but Gabo is still a very prominent variety.

As a result of increases in the acreages sown to varieties with some resistance to leaf rust and possibly as a result of a more detailed survey of the field, much greater variation is now known to occur. At least 21 strains, all markedly different, can be readily found either in the field or in nurseries when the glasshouse tests are made on the appropriate varieties. The complete picture of the area can only be obtained by a study of the strains in New Zealand, and this has been possible through the courtesy of Dr. H. C. Smith, who has submitted samples for several years.

TABLE 1.

Reactions of the Standard Differentials to Leaf Rust Strains in the Australia-New Zealand Area.

	Malakof.	Webster.	Carina.	Loros.	Brevit.	Mediterranean.	Democrat.	Hussar.
10	4	4	4	4	4	;	;	x+
15	;	;	;	;	;	4	4	x+
26	;	x	4	4	4	;	;	4
64	4	x	x	4	4	;	;	x^{+}_{+}
68	;	4	4	4	4	;	;	x^{+}_{+}
76	;	x	x	4	4	4	4	x^{+}_{+}
122	4	4	4	4	4	4	4	x^{+}_{+}
135	;	x	x	x	x	;	;	x^{+}_{+}
162	;	4	4	4	4	4	4	x^{+}_{+}

In contrast to Australia there has been no breeding for leaf rust resistance in New Zealand, and the prevalent strains there are identical with the ones found in Australia during the 1920–1945 period. These strains are now extremely rare in Australia since they are unable to attack Gabo. The other strains present in New Zealand are identical with the prevalent strains of eastern Australia, and it is presumed that they have been transported aerially across the Tasman Sea. Apparently they have been unable to build up sufficiently to be predominant among the leaf rust population and, since Gabo is not widely grown in that country, they have had no advantages over the strains present earlier.

In arriving at a satisfactory system of nomenclature for leaf rust strains in the Australia-New Zealand geographical area, use has been made of the differential varieties and the key given by Johnston and Levine (1955), and to that extent some international co-ordination has been maintained. It is not difficult to obtain from that table a description that adequately fits the strains of Australia and New Zealand, and those given by Johnston and Levine as races 10, 15, 26, 64, 68, 76, 122, 135 and 162 meet the requirement. Within each group, however, further subdivision is necessary.

The system of designation differs from that proposed for North America in that use is made of a very satisfactory scheme that has been adopted for the races of *Phytophthora infestans* (Black *et al.*, 1953).

The North American system incorporates the reaction on the standard differentials, the supplementals and, as well, specifies the year in which these latter were in use. A designation 15–NA59–1 would indicate race 15 on the standard differentials and race 1 on the supplementals in use in 1959. It is proposed that the same combinations of reactions on the supplementals will have the same race number. Thus 5–NA59–1 will differ from 15–NA59–1 on the standard varieties, but will be identical with it on the supplementals in use in 1959.

In the scheme suggested for this area a determination is first made on the standard set of varieties. From this the broad classification results by reference to the table of Johnston and Levine. This is followed by the geographical area Anz and the classification as determined on the supplemental varieties. These are numbered in a standardized way Thew-1, Gaza-2, Spica-3, Kenya 1483-4 and Klein Titan-5. If an isolate which on the standard set is 26 is avirulent on the 4 supplementals the designation is strain 26-Anz-0. An isolate which conforms to 26 and attacks Thew alone among the supplementals would be called strain 26-Anz-1; strain 26-Anz-2 and 26-Anz-3 are virulent on Gaza and Spica respectively, but on no other variety of the supplemental set. Strain 26-Anz-1,2 attacks Thew and Gaza, while strain 26-Anz-1,2,3,4 attacks all the supplementals except Klein Titan. Strain 162-Anz-1,2,3,4 would be indistinguishable from 26-Anz-1,2,3,4 on the supplementals, but would be very different from it on the standard set. As further supplemental differentials become useful they will be added as necessary.

The North American system provides for additions to or deletions from the group of supplementals by specifying a particular year. As no deletions are envisaged at present from the set of 5 varieties given above, the scheme will only accommodate additions to it. As many varieties of potential value as differentials or as parents are constantly under test, their reactions to the existing strains are almost certainly known. For example, Klein Titan, which has been highly resistant to all Australian strains for many years, was attacked by one isolate in the 1960–61 survey. It has only recently been added to the list of supplemental varieties, although as a source of resistance to all strains it has been tested with all field collections.

The Supplemental Varieties.

The varieties Thew, Spica and Kenya W1483 each have a single gene controlling the resistance they possess. The gene from Thew which has been so effective in Australia in differentiation of strains has been of no value in North America where Thew has been found susceptible. This gene is present in many varieties other than Thew. It occurs alone or in combination with some other gene for resistance. Certain Kenya varieties possess the same resistance as Thew and, from the pedigrees given by Dixon (1960), it is clear that it was used as a parent in breeding in that country. This gene is also known to be present in Norka from the work of Pugsley and Carter (1953), and apparently in that variety it is combined with the gene from Malakof. Consequently to Australian strains of leaf rust Norka may be susceptible or have one or two genes for resistance, depending on the strain that is used. Against strains such as 26-Anz-0 (see Table 2), both the Thew and the Malakof components will operate. The Thew gene is extremely closely linked with a gene controlling resistance to powdery mildew and presumably in the study of Norka reported by Mains (1934), where independence was found, he worked with Malakof resistance to leaf rust and the Thew resistance to powdery mildew.

The Thew gene for leaf rust resistance has never been satisfactory as a source of resistance in breeding. Selection experiments show there is a high mutation rate in the organism for virulence on Thew. Strains virulent on it can be readily selected from single spore cultures of avirulent strains. Consequently for most strains avirulent on Thew there is a virulent counterpart. Cytogenetical work on this resistance suggests that the gene concerned is on chromosome XI (Longwell and Shirky, 1951).

The resistance of Gaza (*T. durum*) has been used in the breeding of the varieties Gabo and Koda and for many years was highly effective against the strains of leaf rust found in Australia and New Zealand. This resistance has also figured in the pedigree of the Kenya wheats as shown by Dixon (1960). Kenya Farmer, which is resistant to the local strains avirulent on Gaza, but susceptible to the others, appears to have inherited the resistance from the Bobin^3 × Gaza line used in its pedigree.

Timstein also possesses the resistance of Gaza and this has been passed on to the variety Lee, a variety important in North America and possibly a useful supplemental variety in that geographical area.

Two varieties recently released in Australia, Gamenya and Mengavi (Watson *et al.*, 1960) have been selected for their leaf rust resistance and combine the resistance of Mentana W1124 with that of Gabo. The combination becomes evident when tests with strain 76-Anz-0 are made. The resistance of Mentana is ineffective, but that of Gabo protects them. The single gene of Gabo for resistance to *P. graminis* var. *tritici* is linked in repulsion with the leaf rust resistance of Mentana on chromosome X (Luig, 1960). During the course of selection the linkage was not broken in the case of Gamenya and consequently this variety has the resistance of Mentana to leaf rust but lacks the resistance of Gabo to stem rust. Mengavi, on the other hand, is a recombination type possessing the two genes for resistance, one from Gabo to stem rust, the other from Mentana to leaf rust. Gabo, Gamenya and Mengavi do not have the full resistance of Gaza to leaf rust as apparently all the genes concerned in resistance have not been transferred from the *T. durum* parent. Such a result is found frequently in many interspecific crosses. The genetic nature of the leaf rust resistance of Gaza has not been fully worked out and the gene present in Gabo has not been definitely located on any particular chromosome.

Since no 42 chromosome derivatives are available which give the very sharp hypersensitive reaction of Gaza to strains such as 26-Anz-0, use is made of the latter rather than of Gabo in strain identification.

Pathological tests suggest that a number of varieties received from Egypt as *T. durum* would be interchangeable with Gaza as a suitable supplemental differential.

The third variety Spica W2341 is reported to have originated from a cross between an unfixed hybrid (Three Seas × Kamburico *T. durum*) and an unnamed selection (Pusa × Flora 3202), (Rosser, 1952). It is now a valuable commercial variety having resistance to the important strains of stem rust. When it was first made available for cultivation it was resistant to many of the strains of leaf rust, but susceptibility became evident at a time when leaf rust was also found on the varieties Hofed, Hope, H-44 and Renown. Subsequent tests have established that Spica can be used to differentiate those strains virulent on Hope and derivatives of it. The reactions of Spica are not entirely satisfactory for seedling work as resistance is indicated by a mixture of ";", "2" and "4" type reactions on the one leaf. To some strains such as 122-Anz-1,2 the reactions of Spica and Renown are very definite, with much hypersensitivity, but to others the 4 type reactions predominate although the seedlings are still classed as resistant. There has not been complete correlation between the reactions of Spica and Renown on the one hand, and those of any of the supplementals listed for trial in North America on the other. The variety La Porte received from Dr. R. M. Caldwell has shown the closest agreement with Spica in reaction type and Hope figures in the pedigree.

There has, however, been some correlation between the reactions of Spica and Lee, although impure seed has presented difficulties in this latter variety. Lee is resistant to strains avirulent on Gaza and strains virulent on Spica cannot always attack Lee on account of this protection. Strains virulent on Gaza but unable to attack Spica cannot attack Lee, although the latter shows some variation to this group of strains. Lee has been derived from the cross (Hope × Timstein) and it appears to combine the resistance of Gaza and of Hope to the Australian strains of leaf rust. For this reason it has not been considered a suitable supplemental variety, but rather a variety for detecting those strains virulent on both Gaza and Spica. The cytogenetical work on the locations of this resistance is not yet complete.

The fourth variety among the supplementals is Kenya 112–E–19–J(L) W1483 R.L. 1873, and although the resistance has been found to be simply inherited, its origin has not yet been determined. The resistance is marked by very sharp hypersensitivity to 23 of the 27 strains listed, but to the other four it shows complete susceptibility as seedings. Studies are in progress to combine the gene from Kenya 1483 with other genes for resistance to assist the survey work, but otherwise the gene has been dropped from the breeding programme. The location of this gene in the chromosomes is still unknown, but it appears to be associated with distorted F_2 ratios (unpublished work).

Klein Titan W2553 D.1.V. 396 (Barleta 7d × Americano 44d) is the fifth of the supplemental varieties and the latest to be added to this group. From field surveys only one collection has been found to comprise a strain virulent on this variety. During the course of this work it has been inoculated with more than 1,000 field accessions and it has normally shown a very high resistance. In Table 2 the strain taken in the field from

TABLE 2.

Reactions of Five Supplemental Differentials to Leaf Rust Strains in the Australia-New Zealand Area.

——	Thew—1.	Gaza—2.	Spica—3.	Kenya 1483—4.	Klein Titan—5.	Previous Designations.		
						Water-house (1952).	Watson 1958.	Watson *et al.* (1960).
10-Anz—1, 2, 3	S	S	S	R	R			
15-Anz–0	R	R	R	R	R			
15-Anz–1	S	R	R	R	R			
26-Anz–0	R	R	R	R	R	95	95-Anz–1	
26-Anz–1	S	R	R	R	R	26	26-Anz–1	
26-Anz–3	R	R	S	R	R		95-Anz–2	
26-Anz–1, 3	S	R	S	R	R		26-Anz–2	
64-Anz–1, 2	S	S	R	R	R		64-Anz–1	
68-Anz–2	R	S	R	R	R	138 AB	68-Anz–1	
68-Anz–2, 3	R	S	S	R	R		68-Anz–2	
68-Anz–1, 2, 3	S	S	S	R	R	138 BB	68-Anz–3	
68-Anz–1, 2, 3, 4 ..	S	S	S	S	R			
68-Anz–1, 2, 3, 5 ..	S	S	S	R	S			
76-Anz–0	R	R	R	R	R			
76-Anz–2, 3	R	S	S	R	R			
76-Anz–1, 2, 3	S	S	S	R	R			
122-Anz–1, 2	S	S	R	R	R			
135-Anz–2	R	S	R	R	R	135 AB	135-Anz–1	
135-Anz–1, 2	S	S	R	R	R	135 BB	135-Anz–2	
135-Anz–2, 3	R	S	S	R	R		135-Anz–3	
135-Anz–1, 2, 3	S	S	S	R	R		135-Anz–4	
135-Anz–2, 3, 4	R	S	S	S	R			
135-Anz–2, 3, 4, 5 ..	R	S	S	S	S			
162-Anz–2	R	S	R	R	R		163-Anz–1	163-Anz–1
162-Anz–1, 2	S	S	R	R	R			163-Anz–2
162-Anz–1, 2, 3	S	S	S	R	R			
162-Anz–1, 2, 3, 4 ..	S	S	S	S	R			

R = resistant ; S = susceptible.

Bongeen, Queensland, and sent in by Mr. D. Rosser, appears as race 68 on the standard set of differential varieties and has been classified as strain 68-Anz-1,2,3,5. A number of South American wheats which bear the name of Klein have been tested with this strain of rust, but none differentiates it in the same way as Klein Titan. Klein Lucero W2012 shows the same resistant reaction when inoculated with strains either avirulent or virulent on Klein Titan. Apparently it represents a very different genotype.

A second strain attacking Klein Titan was found among the progeny from aecidial infections on *Thalictrum flavum*. This strain attacks Kenya 1483 and has been designated 135-Anz-2,3,4,5.

The Search for Increased Virulence.

By means of systematic field surveys and careful observations on the rust reactions of genetical material in plant breeders' nurseries it has been possible, as shown above, to collect and classify strains representing a wide range of virulence. These strains between them have the ability to attack all members of the standard differential series, strain 122-Anz-1,2 having the widest host range on this latter group. It is now well known that the strains with the widest host range are not necessarily the most prevalent in the field and consequently in the breeding work little attention has been given to many of the prevalent but relatively avirulent strains of the commercial wheat districts.

All breeding material, especially that in the early generations, is grown at Castle Hill approximately 200 miles east of the fringe of the wheat belt. At this centre all local leaf rust strains are maintained under controlled conditions and, provided they have been collected in the field, any of them may be used in creating epidemics. Under wheat belt conditions in New South Wales, by way of contrast, naturally occurring leaf rust epidemics would be caused mainly by strains 135-Anz-2,3, 135-Anz-1,2,3 and 68-Anz-1,2,3. On the Darling Downs in Queensland the same strains would be prevalent in the nurseries, but an important component would be 68-Anz-1,2,3,4. In these districts, provided their dissemination was assisted by interspersing Gamenya or Mengavi among the rows, strains 76-Anz-2,3, 76-Anz-1,2,3, 162-Anz-1,2,3 and 162-Anz-1,2,3,4 would also be common. Strains such as 10-Anz-1,2,3, 64-Anz-1,2 and 122-Anz-1,2 would be unlikely in the nurseries as they have not yet been found in the wheat districts.

At Castle Hill selections are made using relatively few strains in planned epidemics although spores of common strains are wind borne from other areas within the County of Cumberland to the nursery. Seedlings of hybrid material are tested in the glasshouse with strains 10-Anz-1,2,3, 122-Anz-1,2 and 162-Anz-1,2,3,4. Nursery epidemics are developed in which survival of these strains is assisted by planting the appropriate border rows. With the exception of pathogenicity on Klein Titan these three strains represent all special pathogenic abilities present in the other strains naturally occurring. The aim is to select for resistance to those strains having the widest host range and to examine critically all new resistant hybrids which may serve to screen out virulent mutants or somatic recombinants from them. The effectiveness of this approach has been shown by the isolation of many new strains from the breeding nursery and the incorporation of resistance to them before they have become prevalent in the recognized wheat growing districts.

Strains 10-Anz-1,2,3 and 122-Anz-1,2 were selected in this way at Castle Hill and strain 162-Anz-1,2,3,4 was selected from a nursery at Brookstead, Queensland. Each has been used for a specific purpose in the breeding programme to combine in a genetic background of Gamenya the genes for physiologic resistance from Norka and Mentana with the adult plant resistance of Chinese. In deriving this combination, seedlings of the appropriate hybrids that were resistant to a combination of strains 10-Anz-1,2,3 and 162-Anz-1,2,3,4 were tested as adult plants for their resistance to strain 122-Anz-1,2. In this way it has been possible to get the physiologic resistance of Norka to all strains except 10-Anz-1,2,3, 64-Anz-1,2 and 122-Anz-1,2 combined with the physiologic resistance of Mentana to all strains to which the latter is resistant. Resistant seedlings having this combination and developing resistance to strain 122-Anz-1,2 as adult plants were found to have the three sources of resistance combined, the gene for adult plant resistance being effective against all local strains. This and similar procedures have been found essential to broaden the base on which resistance to leaf rust depends.

The search for new combinations of genes for pathogenicity goes on hand in hand with efforts to combine genes for resistance. In addition, teleutospores of the most virulent strains are collected each year and used to infect the alternate host *Thalictrum flavum*. The aecidial material is increased on a susceptible variety of wheat and the resulting uredospores used to inoculate seedlings of all sources of resistance. Among the strains listed in Table 2 are two, viz.: strain 135-Anz-2,3,4 and strain 135-Anz-2,3,4,5 that have arisen from sexual progeny in this way. Neither of them has been isolated in the field. One of them, 135-Anz-2,3,4,5, is of some significance in that it attacks Klein Titan.

Acknowledgements.

During the course of this work much of the inoculation was done by Mr. D. J. S. Gow. His assistance is much appreciated. We acknowledge financial help from the Wheat Industry Research Council and the University of Sydney Research Grant.

TABLE 3.

Reactions of Supplemental Varieties under Test in North America when Inoculated with Leaf Rust Strains Present in the Australia-New Zealand Area.

—	—	10-Anz.	26-Anz.				64-Anz.	68-Anz.				76-Anz.			122-Anz.	135-Anz.				162-Anz.			
		1, 2, 3	0	1	3	1, 3	1, 2	2, 3	1, 2, 3	1, 2, 3, 4	1, 2, 3, 5	0	2, 3	1, 2, 3	1, 2	2	1, 2	2, 3	1, 2, 3	2	1, 2	1, 2, 3	1, 2, 3, 4
Agrus ..	.. W2502	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;
Newsar ..	.. W2497	x	x$^{+}_{+}$	4	4	4	x	x+	x+	x	x	x$^{+}_{+}$	x	x	x	x$^{+}_{+}$	x$^{+}_{+}$	x	x$^{+}_{+}$	x	x	x=	x=
Waban ..	.. W2495	Seg.	Seg.	Seg.	Seg.	Seg.	x=	Seg.	Seg.	4	Seg.	;1	;	;	4	Seg.	Seg.	Seg.	Seg.	4	4	4	4
C.I. 13278	.. W2503	Seg.	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;
Wardal ..	.. W2496	x+	;	;	;	;	x	4	4	4	4	;	;	;	4	;	;	;	x^{-}	4	4	4	4
Sinvalocho	.. W2013	;	;	;	;	;	;	;	;	;	;	4	4	4	4	;	;	;	;	4	4	4	4
Klein Lucero	.. W2012	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;
Westar ..	.. W2498	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Wesel ..	.. W2499	x+	4	4	4	4	x	x	x	x	x	x	x=	;	x=	x	x	x	x	x	x	x	;
Exchange..	.. W2554	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cr}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}	3^{cn}
Rio Negro	.. W2556	;	;	;	;	;	;	x=	x=	x=	x	;	;	;	;	;	;	;	;	;	;	;	;
Colotana 266/51	W2555	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Lee ..	.. W2084	4	Seg.	Seg.	Seg.	Seg.	;4	4	4	4	4	Seg.	4	4	;4	;4	;4	Seg.	4	Seg.	;4	4	4
Aniversario	.. W2097	;	;	;	;	;	x	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;
Transfer ..	.. W2382	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;	;

Seg. = Segregating.

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